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Microstructural changes and Pb mobility during the zircon to reidite transformation: Implications for planetary impact chronology

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Abstract

Impact events modify and leave behind a complex history of rock metamorphism on terrestrial planets. Evidence for an impact event may be recorded in physical changes to minerals, such as mineral deformation and formation of high *P-T* polymorphs, but also in the form of chemical fingerprints, such as enhanced elemental diffusion and isotopic mixing. Here we explore laboratory shock-induced physical and chemical changes to zircon and feldspar, the former of which is of interest because its trace elements abundances and isotope ratios are used extensively in geochemistry and geochronology. To this end, a granular mixture of Bishop Tuff sanidine and Kuehl Lake zircon, both with well characterized Pb isotope compositions, was prepared and then shocked via a flat plate accelerator. The peak pressure of the experiment, as calculated by the impedance matching method, was ~24 GPa although a broader range of *P-T* conditions is anticipated due to starting sample porosity. Unshocked and shocked materials were characterized via scanning electron microscopy (SEM), electron backscatter diffraction (EBSD), and Raman spectroscopy. These methods show that the starting zircon material had abundant metamict regions, and the conversion of the feldspar to glass in the post-shock material. Analyses of the shocked product also yielded multiple occurrences of the high-pressure $ZrSiO_4$ polymorph reidite, with some domains up to 300 μm across. The possibility of U-Pb system disturbance was evaluated via laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) and secondary ion mass spectrometry (SIMS). The isotopic data reveal that disturbance of the U-Pb geochronometer in the reidite was minimal (<2% for the main U-Pb geochronometers). To better constrain the *P-T* conditions during the shock experiment, we complement impedance matching pressure calculations with iSALE2D impact simulations. The simulated results yield a range of *P-T* conditions experienced during the experiment and show that much of the sample may have reached >30 GPa, which is consistent with formation of reidite. In the recovered shocked material, we identified lamellae of reidite, some of which interlock with zircon lamellae. Reidite {112} twins were identified, which we interpret to have formed to reduce stress between the crystal structure of the host zircon and reidite. These two findings support the interpretation that shear transformation enabled the transition of zircon to reidite. The size and presence of reidite found here indicate that this phase is probably common in impact-shocked crustal rocks that experienced ~25 to ~35 GPa, especially when the target material has porosity. Additionally, shock loading of the zircon and transformation to reidite at these pressures in porous materials is unlikely to significantly disturb the U-Pb system in zircon and that the reidite inherits the primary U and Pb elemental and isotopic ratios from the zircon.

Keywords: Impact, flat-plate shock experiments, zircon, reidite, sanidine, U-Pb dating